**3GPP TSG-SA WG4 Meeting #131-bis-eS4-250536**

**Online, 11 - 17 April 2025**

**Source: Philips, Nokia, InterDigital**

**Title: [FS\_Beyond2D] Evaluation of multi-view plus depth with preliminary results**

**Agenda item: 9.7**

**Document for: Agreement**

**1. Introduction**

This document provides input on the evaluation of Scenario 3: Streaming of Multi-view plus depth Produced Content (TR 26.956 0.3.0, section 7.4), with some first results. Currently only one sequence was prepared. The aim is to add 2-4 more sequences for this scenario.

**2. Proposal**

The proposal is to add the provided information to a new section x.y of the PD.

**3. Attachments**

* Configuration files
* Encoder log files
* Objective results
* Pose trace videos (on a temporary FTP)

## x.y Evaluation of multi-view plus depth produced content

### x.y.1 Test sequences

The evaluation has been performed on the sequences listed in Table xy1.

[Ed.(BK): The aim is to add 2-4 more sequences for this scenario.]

The Breakfast sequence is part of the MIV CTC [XY1] but has not been used for the development of ISO/IEC 23090-12:2023.

Table xy1: Test sequences for the evaluation of the scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sequence** | **ID** | **Provider** | **Frames** | **Resolution** | **Bit depth** | **Color format** |
| Breakfast  (Figure xy1) | D02 | InterDigital | 97 @ 30 Hz  3.2 s | 1920 x 1080  5 x 3 views | texture: 10b  depth: 16b | texture: 4:2:0 BT.709  depth: 4:2:0 full range linear |
| ... |  |  |  |  |  |  |
| ... |  |  |  |  |  |  |
| ... |  |  |  |  |  |  |

A group of people sitting at a table

AI-generated content may be incorrect. A group of people sitting at a table

AI-generated content may be incorrect.

Figure xy1: Breakfast sequence (view 7, frame 0)

### x.y.2 Software

The software that has been used for the evaluation of the scenario is listed in Table xy2. All software has been built from source using Python 3.10, LLVM 18.1.8 with help of the install.py script of TMIV, as follows:

*# environment with python, clang and clang++ on the path*

git clone https://gitlab.com/mpeg-i-visual/tmiv.git

cd tmiv

python -m venv venv

. venv/bin/activate

python -m pip install --upgrade pip

pip install -r requirements.txt

scripts/install.py clang-release

Table xy2: Software used for the evaluation of the scenario

|  |  |  |
| --- | --- | --- |
| **Software** | **URL** | **Version** |
| Test model for MPEG immersive video (TMIV) | <https://gitlab.com/mpeg-i-visual/tmiv> | 24.0[[1]](#footnote-2) |
| HEVC test model (HM) | <https://vcgit.hhi.fraunhofer.de/jvet/HM> | 18.0 |
| Quality metrics for immersive video (QMIV) | <https://gitlab.com/mpeg-i-visual/qmiv> | 2.0 |

HM 18.0 was selected based on WG 04/N 0660 [XY2]. An alternative that was tested is Kvazaar 2.3.1. With that encoder it was shown that it is possible to encode MIV with packed video (a single video sub-bitstream for everything) without a rate-distortion loss. The reason is that Kvazaar supports a delta QP map (ROI file) and that enables setting delta QP values for geometry and texture regions. Typically geometry requires a lower QP values than texture. Without similar functionality in HM, but better rate-distortion in general, it was decided to conduct experiments with HM and without packed video.

### x.y.2 Encoding of bitstreams

All sequences have been encoded using the configurations in Table xy3. The configuration files are attached to this document.

* The *full views* (FV) condition serves as an anchor whereby each component of each view is encoded separately as a HEVC Main 10 bitstream. TMIV and MIV are only used for practical reasons (re-use of scripts and carrying metadata).
* The *MIV main anchor* (A) condition is the MIV CTC anchor, defined in ISO/IEC JTC 1/SC 29/WG 04 N 0659. It results in two atlases, each with a texture and geometry component.
* The *Synthesize center view* (SCV) condition produces a single atlas with a texture and geometry component. The aim of this condition is to provide a level 2.5 result by lowering the pixel rate compared to the MPEG anchor.

Table xy3: Encoder conditions

|  |  |  |  |
| --- | --- | --- | --- |
| **Condition** | **Profile** | **Abbreviation** | **Directory name** |
| Full views | HEVC Main 10 | FV | config/full\_views |
| MIV main anchor | HEVC Main 10 MIV 2 (FDIS 23090-12:—) | A | config/miv\_main\_anchor |
| Synthesize center view | HEVC Main 10 MIV Extended (23090-12:2023) | SCV | config/synthesize\_center\_view |

Encoding was performed by running the encode.py script of TMIV with appropriate parameters. For example:

*TMIV\_DIR*/bin/encode.py -i *INPUT\_DIR* -o out -s D02 -n 32 \

-r RP0 -f 0 -v HM -j 4 -t *TMIV\_DIR* \

--config-dir share/config \

-c config/synthesize\_center\_view/SCV\_1\_TMIV\_encode.json \

-m config/synthesize\_center\_view/SCV\_3\_TMIV\_mux.json \

-C share/config/hm/encoder\_randomaccess\_main10.cfg

The only substantial difference between the encoder conditions is the TMIV encoder configuration because the TMIV multiplexer configuration is trivial and the HM configuration is kept to the same random-access configuration for all conditions.

[Ed.(BK): Current results are based on 32 frames with 128 frame pose trace videos. The intent is to use at least 65 frames and at least 260 frame pose trace videos.]

The rate point RP0 is a result without coding of the video sub-bitstreams that can be used to determine how much quality is lost by the pixel pruning prior to video coding. Rates RP1 .. RP4 correspond to the following QP values in Table xy4.

Table xy4: QP values (texture, geometry) of Breakfast for all encoder conditions

|  |  |  |  |
| --- | --- | --- | --- |
| **Rate point** | **Full views** | **MIV main anchor** | **Synthesize center view** |
| RP1 | 25, 6 | 25, 6 | 25, 6 |
| RP2 | 30, 14 | 30, 14 | 30, 14 |
| RP3 | 35, 14 | 35, 14 | 35, 14 |
| RP4 | 43, 20 | 43, 20 | 43, 20 |

### x.y.3 Results

#### x.y.3.1 Example atlas frames

The full views (FV) condition encodes each component of each view separately, e.g. resulting in 30 separate 1920 x 1080 videos for the Breakfast sequence. Figure xy2 and Figure xy3 provide examples of atlas frames for the MIV main anchor (A) and synthesize center view (SCV) conditions. A comparison of pixel rates is provided in Tabe xy5. Note that the size of each atlas is calculated by TMIV based on provided luma picture size, luma sample rate requirements and source characteristics.

A group of people sitting at a table

AI-generated content may be incorrect. A collage of a room with many objects

AI-generated content may be incorrect. A group of people sitting at a table

AI-generated content may be incorrect. A black and white image of a person in a room

AI-generated content may be incorrect.

Figure xy2: Video components of condition A with left to right: texture for atlas 0 and 1, geometry for atlas 0 and 1

A group of people sitting at a table

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Figure xy3: Video components of condition SCV with left texture and right geometry

#### x.y.3.2 Pixel rate

The pixel rates per video sub-bitstreams and the aggregate pixel rate are depicted in Table xy5.

Table xy5: Pixel rates for all sequences and conditions:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Condition** | **Sequence** | **Components** | **Sizes** | **Aggregate size** (# luma samples) | **Aggregate luma sample rate** |
| FV | D02 | 15 x texture  15 x depth | 1920 x 1080  1920 x 1080 | 59.3 M | 1.74 G/s |
| A | D02 | 2 x texture  2 x geometry | 1920 x 4608  960 x 2304 | 21.1 M | 0.618 G/s |
| SCV | D02 | texture  geometry | 2880 x 2432  1440 x 1216 | 8.3 M | 0.245 G/s |

#### x.y.3.2 Rate-distortion characteristics

The aggregate bit rates are provided in Table xy6, and average IV-SSIM values are provided in Table xy7.

[Ed.(BK): Tune QP values to have more overlap between conditions. After QP tuning, provide per-sequence rate-distortion graphs to make it easier to interpret the objective results; and calculate BD-rates to compare the conditions.]

Table xy6: Aggregate bit rates for all sequences and conditions:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Condition** | **Sequence** | **Aggregate bit rate [Mb/s]** | | | |
|  |  | **RP1** | **RP2** | **RP3** | **RP4** |
| FV | D02 | 69.8 | 42.7 | 26.9 | 12.7 |
| A | D02 | 40.1 | 23.1 | 13.9 | 6.1 |
| SCV | D02 | 9.5 | 5.7 | 3.5 | 1.6 |

Table xy7: IV-SSIM values averaged over all source views, for all sequences and conditions:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Condition** | **Sequence** | **Average IV-SSIM** | | | | |
|  |  | **RP0** | **RP1** | **RP2** | **RP3** | **RP4** |
| FV | D02 | 0.998 | 0.986 | 0.981 | 0.974 | 0.947 |
| A | D02 | 0.990 | 0.981 | 0.978 | 0.971 | 0.946 |
| SCV | D02 | 0.972 | 0.964 | 0.959 | 0.952 | 0.926 |

#### x.y.3.3 Pose trace videos

For each bitstream, that is for each sequence for each encoder condition and for each rate RP0 .. RP4, three pose trace videos have been rendered. A bitstream can be decoded and rendered using a command like this:

*TMIV\_DIR*/bin/TmivDecoder -j 1 -n 32 -N 128 -s D02 -r RP3 -P p01 \

-c config/synthesize\_center\_view/SCV\_4\_TMIV\_decode.json \

-p inputDirectory out -p outputDirectory out \

-p configDirectory share/config

The decoder configurations differ only in path formats: there is no out-of-band information for RP1 .. RP4.

The pose trace videos are available for informal expert viewing at the following links:

<https://fileshare.ehv.campus.philips.com/private/20250422-RD58423C1CCB54A24970EE11A66D162DC>

<sftp://anonymous@fileshare.ehv.campus.philips.com/private/20250422-RD58423C1CCB54A24970EE11A66D162DC/>

This directory will be automatically removed after Tuesday, April 22, 2025.

### x.y.4 References

[XY1] Common test conditions for MPEG immersive video, ISO/IEC JTC 1/SC 29/WG 04/N 659, April 2025, url: <https://www.mpeg.org/wp-content/uploads/mpeg_meetings/150_OnLine/w25084.zip>, Online.

[XY2] Encoder guidelines for MPEG immersive video, ISO/IEC JTC 1/SC 29/WG 04/N 659, April 2025, url: <https://www.mpeg.org/wp-content/uploads/mpeg_meetings/150_OnLine/w25085.zip>, Online.

1. To be pulished soon. A zip-file can be provided to non-MPEG members on request. [↑](#footnote-ref-2)